

## Final Report

### "Radiation Emission of Atoms and Molecular and Electron Impact"

AFOSR Grant F49620-02-1-0036

The research conducted under this project is in the general area of atomic and molecular collisions. The specific works carried out include the following items.

1. We have performed a systematic study of the relations between angular momentum coupling in the excited state of rare-gas atoms and electron-impact excitation cross sections. Take for instance, the excited  $2p^5 3p$  configuration of neon. The  $2p^5$  core has orbital angular momentum  $P_c$  and spin angular momentum  $s_c$ , and the outer electron  $3p$  has orbital angular momentum  $P_o$  and spin angular momentum  $s_o$ . These four angular momenta interact with one another and the way they couple together has profound influences on the electron-impact excitation cross sections. The coupling of  $P_c$  and  $P_o$  is governed by the Coulomb interaction and the coupling of  $s_c$  and  $s_o$  by the exchange interaction, both of which can be quantified by the relevant Slater-Condon parameters. The coupling of  $P_c$  with  $s_c$  and of  $P_o$  with  $s_o$  are governed by the spin-orbit interaction which can be quantified by the spin-orbit parameters. The overall coupling scheme is determined primarily by the competition of the Slater-Condon parameters with the spin-orbit parameters. We have introduced the ratio of the spin-orbit parameters to the Slater-Condon parameters (referred to the competition ratio for convenience) as a way to gauge to coupling scheme. Across the series of  $Ne(2p^5 np)$ ,  $Ar(3p^5 np)$ ,  $Kr(4p^5 np)$ ,  $Xe(5p^5 np)$  we have found interesting correlations between electron-impact excitation cross sections and the competition parameter. For instance the ratio of the cross sections for the two  $J=0$  levels is very close to the same universal function of the competition parameter for all four atoms. A paper on this study has been published in the *International Journal of Mass Spectrometry*, Vol, 233, 75 (2004).
2. We have examined the influence of radiation trapping on the emission intensity of the  $3p^5 4p \rightarrow 3p^5 4s$  transitions of argon and the resulting pressure dependence of the emission cross sections. Ignoring this effect may lead to serious errors in plasma diagnostic work. We have suggested the use of pressure-dependent apparent excitation cross sections to overcome this problem. We have also performed experiments to improve the standard optical diagnostic techniques. Such experiments includes (a) combining the use of  $3p^5 4p$  and  $3p^5 5p$  emission lines of argon to determine electron temperatures, (b) correcting for the contribution from two-step processes to the  $Ar^+$  emission when one uses a combination of  $Ar$  and  $Ar^+$  emission lines to determine electron temperature. A paper entitled "Application of Excitation Cross Sections to Optical Plasma Diagnostics" has been published in *Journal of Physics D as a Topical Review (invited)*, Vol 37, R143 (2004).

3. The  $3p^5 5p \rightarrow 3p^5 4s$  transitions of argon are in the general wavelength range of 400-470 nm where photomultiplier detection sensitivity is high. Hence these lines are well suited for plasma diagnostics. This is particularly important because in a plasma some of the  $3p^5 5p$  levels are populated mainly by excitation out of the ground level of Ar, but some of the  $3p^5 5p$  levels are populated mainly by excitation out of the metastable levels. We have measured excitation cross sections out of both the ground and metastable levels into several  $3p^5 5p$  levels. Using these results we can predict the relative intensities of several  $3p^5 5p \rightarrow 3p^5 4s$  emission lines under different plasma conditions. Some of our predictions are in good agreement with observation.

## REPORT DOCUMENTATION PAGE

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